

March 24, 1959

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2,879,032

HYDRAULIC TURBINE WITH BY-PASS VALVE

Filed Nov. 21, 1955

2 Sheets-Sheet 1

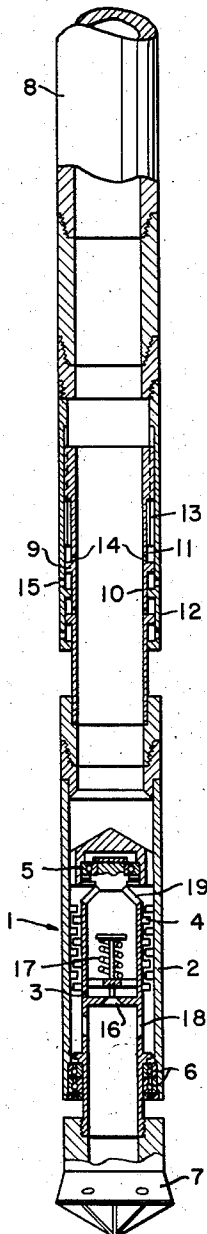


FIG. 1

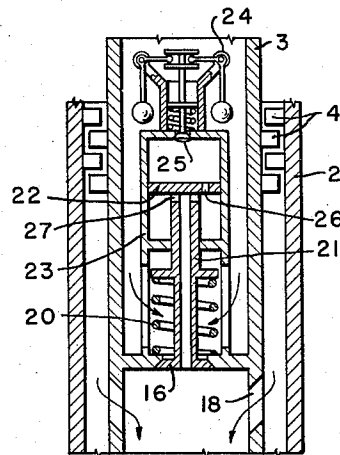


FIG. 5

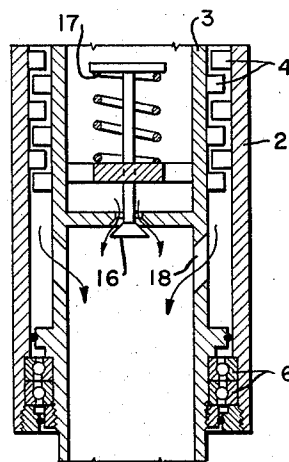


FIG. 2

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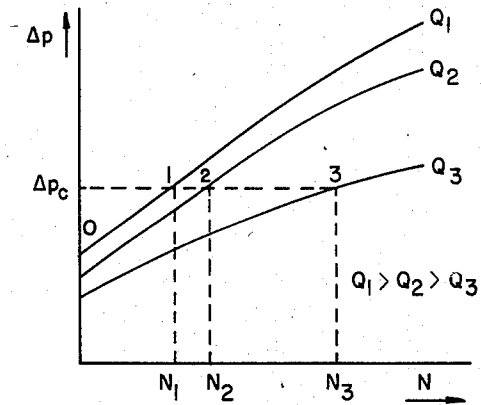


FIG. 3

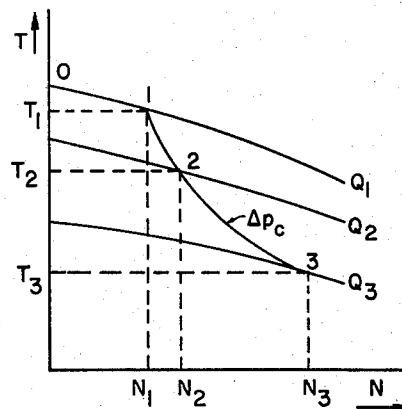


FIG. 4

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2,879,032

HYDRAULIC TURBINE WITH BY-PASS VALVE

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Application November 21, 1955, Serial No. 548,139

Claims priority, application Great Britain
December 10, 1954

5 Claims. (Cl. 255—4)

The present invention relates to well drilling systems as may be used for example in drilling deep bore holes in the surface of the earth with the object of finding salt, sulphur, water, oil or the like.

The invention particularly pertains to well drilling systems of the type in which a tubular drill string, which in operation extends from the top of the bore hole to the bottom, is provided at its lower end with a hydraulic turbine for driving a rotary drill bit. The turbine is driven by fluid pumped down through the drill string, the fluid usually being what is known as a mud flush or drilling fluid. Usually, too, the fluid is ejected through jet openings in the rotary drill bit, and is directed on to the cutting edges to cool them and to remove the cuttings, before circulating back to the surface. When using jet bits, the fluid is directed against the bottom of the bore hole.

When drilling with such a system through formations of varying hardness, the turbine speed may vary between wide limits, as a result of the varying resistance met by the bit. This may lead to stalling of the turbine when drilling in soft formations, or overspeeding in hard formations. In any case excessive deviations from the design speed of a turbine leads to inefficient operation. The turbine speed can be controlled manually by the driller at the top of the bore hole by varying the weight on the bit and/or the circulation rate of the mud flush which is supplied through the drill string to the turbine, in accordance with information, which is obtained about the turbine operation, such as the turbine speed or the pressure drop across the turbine. It is, however, often very difficult to communicate these measured variables from the bottom of the bore hole to the surface.

These difficulties may be partly overcome by employing a system, for example that described in U.S. patent application No. 548,048, filed November 21, 1955 in which a ram device is interposed with the hydraulic turbine between the drill string and the rotary drill bit.

The ram device described comprises two hollow telescopic members, the inner one of which provides a channel for the passage of fluid from the drill string to the bit and which members have means for preventing relative rotational movement between them, one of said members being provided with one or more pistons, which co-operate with an equal number of cylinders formed on the other member, each piston dividing the cylinder with which it co-operates into two cylindrical spaces. The ram device also comprises means for connecting the cylindrical spaces located to one side of the pistons to a space in which there is a relatively high fluid pressure in operation, and means for connecting the cylindrical spaces located to the other side of the pistons to a space in which there is a relatively lower fluid pressure in operation. Such ram devices will be referred to in this specification as "ram devices of the type specified."

In the simplest case, the space in which there is a relatively high fluid pressure is the interior of the inner telescopic member, and the space in which there is a lower

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fluid pressure is the exterior of the outer telescope member (i.e. the borehole) so that the fluid pressures are those of the mud flush in the drill string and in the borehole respectively. The pressure difference applied to the pistons, and thus controlling the bit weight, is the difference of these two mud flush pressures, which is equal to the sum of the pressure drops across the turbine and the bit openings, both of which depend on the mud flush circulation rate. As explained in the aforesaid patent specification the bit weight determines the load on the turbine for a given hardness of the formation being drilled, and there is thus an interaction between the ram device and the turbine, which leads to an inter-relationship between the formation hardness, the turbine speed and the mud flush circulation rate. Here again it is important to restrict the variations in turbine speed in operation.

One may define in this connection, the "insensibility" of a system as being the ratio between a range of formation hardness, and the corresponding turbine speed range when drilling through the said range of formation hardness. Thus, the larger the insensibility of a system, the greater the range of formation hardness which may be drilled through without the turbine speed passing outside predetermined limits.

Whilst a system including a ram device represents an improvement on a system without such device, further measures to increase the insensibility are desirable in order to increase the tolerance of a drilling system to formations of varying hardness, thus giving the system more flexibility.

It is an object of the present invention to provide a method and means for increasing the insensibility of well-drilling systems which include a hydraulic turbine either alone or in combination with a ram device as described in the said patent application.

Accordingly it is another object of the present invention to provide a well-drilling system comprising a hydraulic turbine, or a combination of a hydraulic turbine and a ram device of the type specified, interposed between the drill string and a rotary drill bit, and means for circulating fluid through the system whereby the circulation rate through the turbine is varied to keep the turbine speed within restricted limits, by passing part of the fluid through a channel by-passing the turbine.

The passage of fluid through the channel by-passing the turbine may be controlled by a valve responsive either to the pressure drop across the turbine or to the speed of rotation of the turbine. In either case the pressure drop across the turbine is preferably not permitted to rise above a predetermined value.

A further object of the present invention is to provide a well drilling system having a hydraulic turbine, or a combination of a hydraulic turbine and a ram device of the type specified, for location near the lower end of a drill string, the turbine being arranged to drive a rotary drill bit, and means being provided for circulating fluid through the system which includes a channel by-passing the turbine, and means for controlling the flow of fluid through the channel to keep the turbine speed within restricted limits in operation when the fluid is pumped through the drill string at a constant rate.

The means for controlling the flow of fluid through the channel by-passing the turbine may comprise a valve located in the channel, which valve is responsive either to the pressure drop across the turbine or to the speed of rotation of the turbine. In either case the valve preferably operates to prevent the pressure drop across the turbine rising above a predetermined value.

Where the valve is responsive to the pressure drop across the turbine, it may comprise a valve member which is urged towards its closed position by a spring, and which

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in operation is subjected on one side to fluid at the pressure of the fluid at the turbine inlet and on the other side to fluid at the pressure of the fluid at the turbine outlet, in such a manner that the pressure difference acts in opposition to the spring.

Where the valve is responsive to the speed of the turbine it may comprise a valve member urged towards its closed position by a spring, and a centrifugal governor, which, as the speed of rotation of the turbine increases, causes a force to be exerted on the valve member in opposition to the spring. The centrifugal governor may for example control the rate of supply of fluid under pressure to a servo-mechanism, which, as the said rate increases, exerts an increasing force on the valve member in opposition to the spring.

In any of the above cases, the valve may be a sleeve valve.

The channel by-passing the turbine may comprise a channel through the turbine rotor shaft, which is thus hollow, the channel communicating at one end with the turbine inlet and at the other end with the turbine outlet, and containing the valve or other means for controlling the flow of fluid through it.

Further according to the present invention, there is provided a hydraulic turbine for location near the end of a drill string, the turbine being adapted for driving a rotary drill bit, and itself being capable of being driven by a supply of fluid pumped down through the drill string, the turbine being provided with a channel by-passing its blading, and means for controlling the flow of fluid through the channel, so as to maintain the speed of rotation of the turbine within restricted limits in operation.

The said channel may pass through the turbine rotor shaft communicating at one end with the turbine inlet and at the other end with the turbine outlet.

Examples of well drilling systems in accordance with the present invention will now be described with reference to the drawings in which Figure 1 is a diagrammatic cross-sectional view of the ram device/hydraulic turbine arrangement having a by-pass valve, Figure 2 is a diagrammatic cross-sectional view of a by-pass valve, Figure 3 shows the turbine pressure drop/turbine speed ($\Delta p/N$) curves for various values of the circulation rate Q , of the fluid passing through the turbine blading.

Figure 4 shows the torque/turbine speed (T/N) curves, for various values of circulation rate Q , of the fluid passing through the turbine blading and Figure 5 is a diagrammatic cross-sectional view illustrating a servo-motor operated by-pass valve.

Referring first to Figure 1, the turbine 1 comprises a stator housing 2 and a hollow rotor shaft 3, both of which having mounted thereon turbine blading 4. The rotor shaft 3 is supported by bearings 5 and 6, while the rotary drill bit 7, which may be of any suitable type, is connected to the lower end of the shaft 3.

Between the drill string 8 (which is kept stationary or is rotated only very slowly so as to prevent it from sticking) and the hydraulic turbine 1, there is interposed a ram device.

The ram device consists of a number of piston and cylinder combinations (for the sake of simplicity only two of these combinations are shown in the drawing but there may be more), the pistons 9 being connected to the inner hollow cylindrical member 10 and the cylinders 11 being formed within the outer hollow cylindrical member 12. Suitable sealing means may be provided between the pistons 9 and the interior surface of the outer member 12, and for sealing adjacent cylinders 11 from one another. The members 10 and 12 are telescopically arranged, a splined coupling 13 being provided to prevent any relative rotational movement between them. The cylindrical spaces located above each of the pistons 9 are connected to the interior of the inner telescopic member 10 by the ports 14 provided in the wall of the member 10, the ports 14 each being located just above one of the pistons 9,

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whilst the cylindrical spaces located below each of the pistons 9 are connected to the exterior of the outer telescopic member 12 by the ports 15 provided in the wall of the member 12, the ports 15 each being located at the lower end of the one of the cylinders 11 with which they are associated.

It will be clear that the difference existing between the pressure of the mud flush passing through the inner telescopic member 10, and the pressure of the mud flush in the borehole at the outside of the outer telescopic member 12 will be applied to all the pistons 9 and will exert on them a downwards force, which, in combination with the weight of the inner telescopic member 10, the turbine 1 and the bit 7, and the hydrodynamic force generated by the mud flush flowing through the turbine 1 and the bit 7, will constitute the effective bit weight, i.e. the load on the bit.

Inside the hollow rotor shaft 3, there is provided a pressure-sensitive valve 16, which is urged towards the closed position by a compressed spring 17. The valve 16 will be closed for all conditions under which the pressure drop across the turbine 1 is below a predetermined value, and, while it is closed, the mud flush emerging from the inner telescopic member 10 will flow to the openings of the bit 7 through the turbine blading 4 and the ports 18 provided in the wall of the rotor shaft 3. When the pressure drop across the turbine rises above said predetermined value, the valve 16 will be opened, and part of the mud flush will by-pass the turbine blading 4 by entering through the ports 19 (Fig. 1) and flowing through the inside of the rotor shaft 3 and the valve 16. Thus, when the valve 16 is open, the pressure drop across the turbine 1 will remain substantially constant with any increase in the rate of flow of mud flush down the drill string 8 resulting mainly in an increased flow through the by-pass channel.

It will be appreciated that in an alternative arrangement the valve 16 controlling the by-pass channel may be constituted by a piston-operated sleeve valve.

The relation between the turbine pressure drop Δp , the turbine speed N and the circulation rate Q of the mud flush passing through the turbine blading 4 is shown by the curves in Figure 3. The turbine pressure drop/speed ($\Delta p/N$) curves are shown for various circulation rates Q . As indicated in the drawing, the circulation rate Q_1 is greater than Q_2 , which in turn is greater than Q_3 . The valve 16 is set to operate when the pressure difference across it is Δp_c , so that when starting to operate the turbine 3 with a constant mud flush circulation rate Q_1 through the drill string 8, the turbine speed increases from zero up to a speed N_1 at which point the pressure drop across it has increased to Δp_c and the valve 16 is opened. At speeds higher than N_1 , the pressure drop across the turbine will remain substantially equal to Δp_c , the circulation rate through the turbine 3 however continuously dropping as the speed increases passing through the value Q_2 at speed N_2 , the circulation rate through the by-pass valve 16 then being $(Q_1 - Q_2)$. Similarly at the turbine speed N_3 , the corresponding circulation rates are Q_3 and $(Q_1 - Q_3)$.

The variations in the torque delivered by the turbine, as a result of by-passing part of the mud flush, may be seen in Figure 4, which shows the torque/speed (T/N) curves for the various circulation rates Q_1 , Q_2 and Q_3 of the mud flush passing through the turbine blading 4.

It will be appreciated that when starting from the point 0 on the curve Q_1 , the torque will be equal to T_1 when the turbine speed has increased to N_1 . At this moment (see Figure 3) the pressure drop across the turbine is equal to Δp_c and the valve 16 (see Figures 1 and 2) opens. At the speed N_2 , the circulation rate through the turbine will be Q_2 (Figure 3), which corresponds to a torque T_2 , whilst at the speed N_3 the respective values are T_3 and Q_3 .

It will be clear that, although only one curve (in this

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case Q_2) is shown as being representative of the circulation rates lying between the values Q_1 and Q_3 , it is possible to draw intermediate curves for circulation rates lying between Q_1 and Q_3 , in order to be able to plot the curve Δp_0 in Figure 4 more exactly. Figure 4 shows very clearly the effect of the invention, namely that the by-pass valve 16 operates as a means of achieving a rapid rate of change of torque with speed. It will be clear that the greater this rate the greater is the insensibility of the system.

The object of the invention may be attained in another manner by inserting a speed-sensitive valve in the by-pass of the turbine. The valve which is operated by a centrifugal governor is set in such a way that starting from the speed N_1 , an increasing quantity of mud flush is by-passed at increasing turbine speeds. It will be appreciated that this alternative arrangement will also result in the rate of change of torque with turbine speed being much greater than would be obtained with a turbine operating without a by-pass. However, with the speed-sensitive valve the pressure drop across the turbine can be made to decrease as the speed increases, as a result of which the torque/speed curve obtained is even steeper than that shown in Figure 4, thus giving an even greater insensibility.

In a preferred arrangement, the speed-sensitive by-pass valve is constituted by a servo-operated valve, the pressure fluid (mud) supply to the servomechanism being controlled by a centrifugal governor.

Such a by-pass valve is shown in Figure 5, mounted in the interior of the hollow rotor shaft 3. The valve body 16, which is of the mushroom type (but which may also be of the sleeve type) is connected by a hollow stem 21 to the servo piston 22 which is arranged to slide in the servo cylinder 23. The valve body 16 is urged towards its closed position by the compressed spring 20. The cylindrical space below the piston 22 is connected to the turbine outlet space through the ports 27 and the interior of the hollow stem 21. A small bleeding duct 26 is provided through the piston 22. In the head of the cylinder 23, there is mounted a pilot valve 25 which is controlled by a centrifugal governor 24.

When the pilot valve 25 is fully closed at low speeds, the pressures in the space above and below the servo-piston 22 are equalized, owing to the presence of the duct 26, at a value equal to the fluid pressure at the turbine outlet.

When the turbine speed increases, the centrifugal governor 24 opens the pilot valve 25 and fluid from the space inside the shaft 3 enters the space in the servo cylinder 23 above the piston 22. Consequently the pressure in the space above the servo-piston 22 will rise until the rate of escape of fluid through the duct 26 is equal to the rate at which it enters through the pilot valve 25.

The force exerted by the pressure difference on the two sides of the piston 22 will displace the valve body 16 until the force on the piston 22 is in equilibrium with the opposing force due to the compression of the spring 20. The valve will then pass part of the mud flush, which would otherwise flow through the turbine blading 4.

The by-pass valve and the associated mechanism may be so designed that by their action the pressure drop across the turbine is kept substantially constant over the speed range in which it operates, thus giving a torque-speed curve similar to that shown in Figure 4.

It will be appreciated that the influence of the pressure drop prevailing across the valve may be eliminated by designing it as a sleeve valve.

Further, the by-pass valve may be located above the turbine blading.

In general it is desirable to coat all the surfaces of the by-pass valve which are subjected to the erosive action of the mud flow with wear-resisting materials, and to design

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the by-pass valve in such a way that it is readily replaceable.

I claim as my invention:

1. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is circulated through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, the lower end of said rotor extending downwardly below said casing, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a drill bit mounted on the downwardly-extending end of said rotor, open-ended by-pass conduit means in communication between the spaces above and below said turbine blading for by-passing fluid therearound, normally-closed valve means in said conduit means and spring means operatively connected to and normally closing the valve means and responsive to the flow line pressure of said drilling fluid to said turbine adapted to allow said valve means to open automatically when said flow line pressure of the turbine has exceeded a predetermined value.

2. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is circulated through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, the lower end of said rotor extending downwardly below said casing, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a drill bit mounted on the downwardly-extending end of said rotor, open-ended by-pass conduit means in communication between the spaces above and below said turbine blading for by-passing fluid therearound normally-closed valve means in said conduit means within said hollow rotor shaft and spring means operatively connected to and normally closing the valve means and responsive to the flow line pressure of said drilling fluid to said turbine adapted to allow said valve means to open automatically when said flow line pressure of the turbine has exceeded a predetermined value.

3. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is circulated through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, said rotor having a hollow shaft with the lower end thereof extending downwardly below said casing, inlet and outlet fluid ports in said hollow rotor shaft at opposite ends thereof, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a drill bit mounted on the downwardly-extending end of said rotor shaft, normally-closed valve means in said hollow rotor shaft, spring means normally closing said valve means, and a centrifugal governor fixedly secured to said rotor and operatively connected to said valve means within the shaft of said rotor, said governor being adapted to exert on said valve means a force opposite to said spring means.

4. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is circulated through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, said rotor having a hollow shaft with the lower end thereof extending downwardly below said casing, inlet and outlet fluid ports in said hollow rotor shaft at opposite ends thereof, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a drill bit mounted on the downwardly-extending end of said rotor shaft, port means through the wall of said hollow rotor shaft below said turbine blading for admitting fluid discharged from said blading into the lower portion of said shaft above the bit, transverse plate means extending across the hollow shaft of said rotor, said plate means having a flow passage therethrough,

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normally-closed valve means in said transverse plate means within said hollow rotor shaft, spring means normally closing said valve means, and a centrifugal governor fixedly secured to said rotor and operatively connected to said valve means within the shaft of said rotor, said governor being adapted to exert on said valve means a force opposite to said spring means.

5. A fluid-driven turbine unit adapted to be secured to a pipe string for drilling oil and gas wells while a drilling fluid is circulated through said turbine and pipe string, said turbine comprising a stator casing, a rotor supported in spaced relationship for rotation within said casing, said rotor having a hollow shaft with the lower end thereof extending downwardly below said casing, inlet and outlet fluid ports in said hollow rotor shaft at opposite ends thereof, turbine blading carried on the inner wall of said casing and the outer surface of said rotor, a drill bit mounted on the downwardly-extending end of said rotor shaft, port means through the wall of

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said hollow rotor shaft below said turbine blading for admitting fluid discharged from said blading into the lower portion of said shaft above the bit, valve means in said hollow rotor shaft for directing the flow of drilling fluid through said hollow shaft and around said turbine blading, spring means normally closing said valve means, and a centrifugal governor fixedly secured to said rotor operatively connected to said valve means within the shaft of said rotor, said governor adapted to exert on said valve means a force opposite to said spring means.

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